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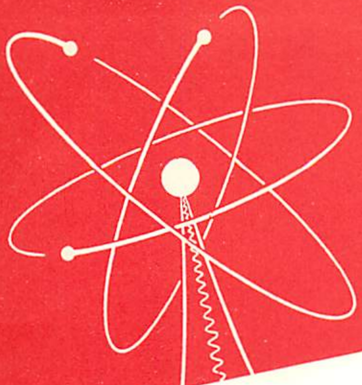
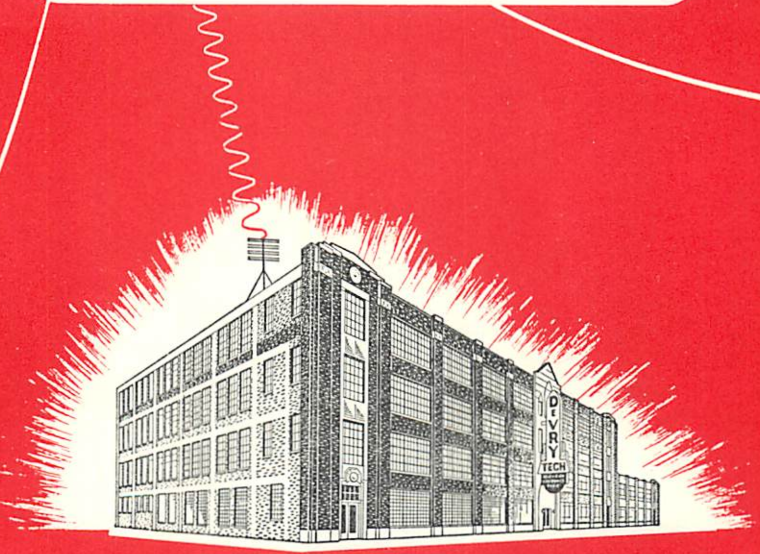


PICTURE TUBES

Lesson T2C-7A



DeVRY Technical Institute
4141 W. Belmont Ave., Chicago 41, Illinois
Formerly DeFOREST'S TRAINING, INC.

T2C-7A

PICTURE TUBES

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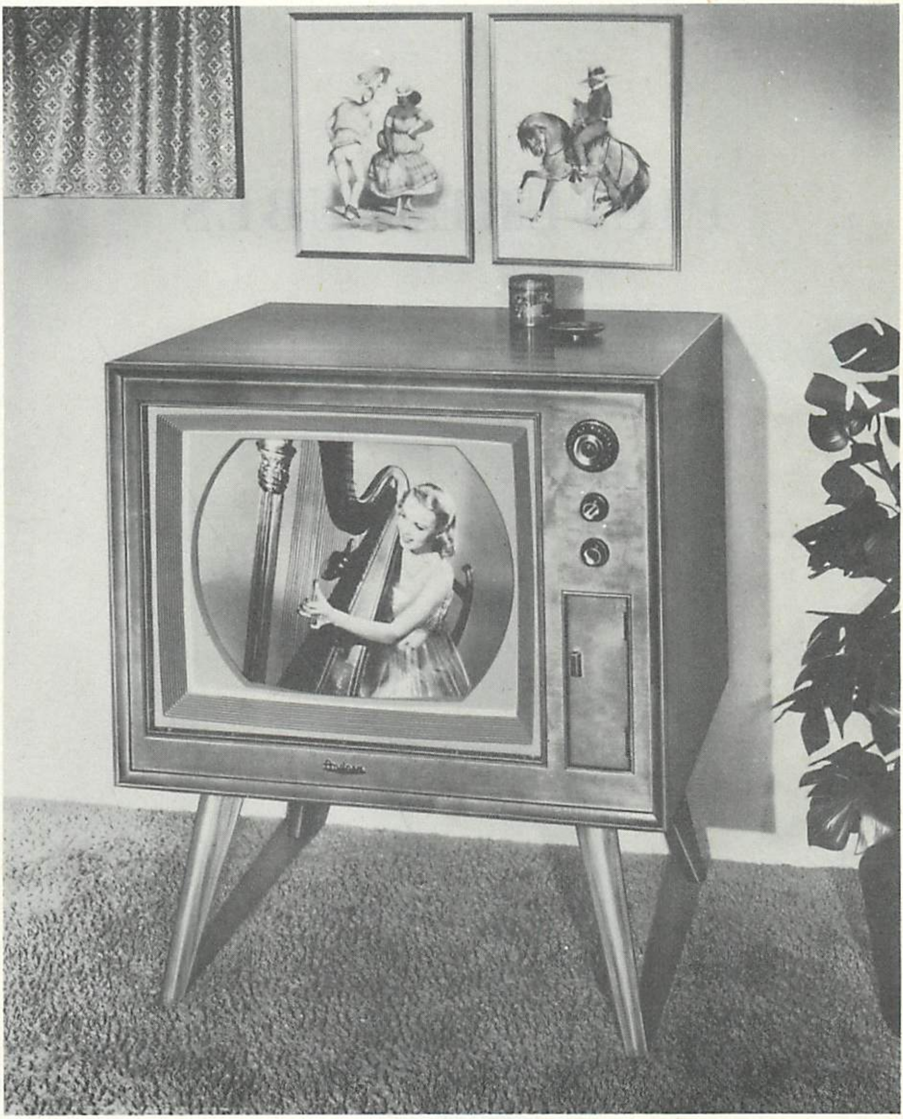

The picture tube provides the viewing screen for the television receiver.
Courtesy Andrea Radio Corp.

PICTURE TUBES

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A true man never frets about his place in the world, but just slides into it by the gravitation of his nature, and swings there as easily as a star.

—E. H. Chapin

PICTURE TUBES

All of the television receiver circuits described in the preceding lessons, as well as most of those yet to be explained, have one purpose in common. This purpose is the reproduction of the televised scene on the receiver screen. In the common, direct view type receivers, the screen actually is the end of a large vacuum tube called the picture tube.

An outstanding example of modern technological development, the television picture tube combines the knowledge gained by extensive research in several branches of science. For example, the study of luminescent materials resulted in the development of "phosphors" which have properties suitable for picture tube screens. Coated on the inside of the picture tube, it is the phosphor which produces light of varying intensity to form the picture.

To produce light, the screen phosphor must be bombarded #2 with tiny particles, in this case, electrons. The necessary stream of electrons is obtained by em- #1 ploying the method developed originally for the cathode ray oscilloscope. That is, a group of electrodes, called the "electron gun", forms a thin beam of fast moving electrons, and directs this beam at the screen. The development of the electron gun required study of electric field action, electrode materials and shapes, and means of providing the required high voltages.

Both magnetic and electric field action were investigated to provide a suitable electron beam, and at the same time sweep the entire screen. In addition, the latter action required the solution of problems in circuit design.

The construction of the large envelope, which contains the screen phosphor at one end and the electron gun at the other, posed many problems for the tube manufacturers. For instance, the completed picture tube is highly evacuated, and the envelope must withstand terrific pressure from the air outside without collapsing.

Finally, the assembly of the picture tube is a complicated procedure. The particular methods employed are the result of experience gained over a period of many years. The phosphor material must be distributed in a very even layer, the electron gun must be aligned with the axis of the tube, and the gun electrodes must be accurately spaced and aligned.

In this lesson, the way in which modern television picture tubes operate is explained in detail. The various types of construction are described, and also the specific applications of these constructions in typical tubes in present use.

PICTURE TUBE PARTS

The television receiver picture tube consists of three major parts: (1) the envelope, (2) the electron gun, and (3) the screen. In general the arrangement of the parts is shown in Figure 1. The envelope is a large bell-shaped bulb which has a cylindrical extension called the neck. It houses and supports the screen at its large end, and the electron gun in its neck. Like the conventional electron tube, the base provides means for connecting the external circuits to the electrodes within the high vacuum envelope.

The electron gun furnishes a narrow beam of electrons, directs them toward the screen, and accelerates them so they strike the screen with sufficient speed to cause fluorescence of the screen material.

Placed around the neck of the tube, a cylindrical electromagnet called the **deflection** yoke causes the electron beam to move up, down, and sidewise to form a light pattern over the entire screen area. At the point where the beam strikes the screen at any instant, a tiny spot of light is produced.

The deflection yoke causes the beam spot to travel across the screen from left to right, and thus trace a horizontal line of light. When the line is completed, the yoke brings the spot quickly back to the left side again, to being another line. At the same time, the spot is moving downward also, so the second line is traced under the first. In this manner, nearly 500 lines are produced to fill the screen with a pattern called a raster. Applied to the electron gun, the video signal varies the beam and therefore the spot intensity. This action produces areas of light and dark on the raster to form the picture.

The picture tube converts the electric signal to light, thus producing a visible image of the transmitted scene. This unit, the type 21YP4A, is typical of the rectangular glass tubes employed in television receivers. The small circular cavity on the side of the bulb provides for connecting to the anode.

Courtesy Westinghouse Electric Corp.

THE LUMINESCENT SCREEN

The picture tube screen is made of tiny crystals of material which have the property of converting electron energy into light. It is this property which enables us to convert electric signals to the variations in light which form the picture.

The term luminescence is defined as the act of absorbing energy and then emitting light without the luminescent material becoming hot enough for incandescence. Luminescence during excitation and within about one ten-millionth of a second after excitation ceases is called fluorescence, while the continuous emission of light for longer intervals than fluorescence is called phosphorescence. Except with substances in the gaseous stage, both fluorescence and phosphorescence always occur together, and therefore, the complete action is best described by the more general term luminescence.

Although the first of the luminescent materials, called "phosphors," was discovered by accident in 1603, the first phosphor suitable for use in cathode ray tubes was not discovered until 1830. This material emitted light which had a greenish color and was suitable for oscilloscope use but unsatisfactory to the television viewer. Now many synthetic phosphors are produced in the laboratory, and practically all present television cathode ray tube screens consist of mixtures of two or more of these materials chosen so that the combined emission characteristics provide white light.

Theory of Phosphor Luminescence

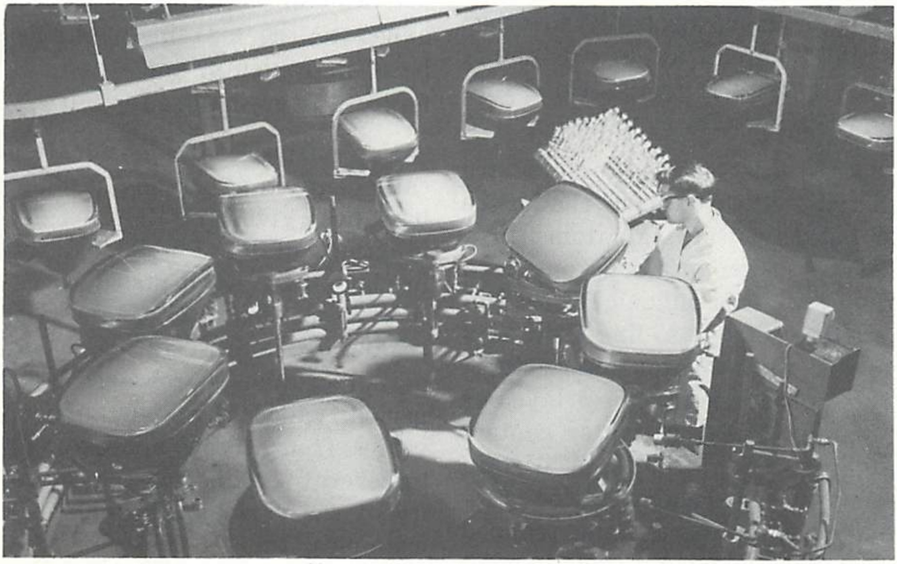
Although no one theory has yet been formulated to explain all of the properties ascribed to phosphors, the following general explanation covers many of the phenomena which have been observed.

All atoms are considered to consist of a nucleus surrounded by a system of electrons that rotate in "shells" of definite "energy levels," which are designated as K, L, M, N, etc. To be absorbed by an atom, impinging energy in the form of light or moving electrons must cause these shell electrons to leave their normal paths and move into shells of higher energy. This added energy causes the atom to change from its normal to an "excited" state. Since this is an unstable condition, the atom returns to its normal state and the surplus energy is emitted in the form of light.

The material used for the screens of picture tubes has a crystalline structure. That is, the atoms or ions are located at definite points in a symmetrical geometric lattice arrangement somewhat as illustrated in Figure 2. This diagram represents the crystal structure of alpha-zinc sulfide known as wurtzite, the white circles indicating the atoms of sulphur, the black dots the zinc atoms and the connecting lines the paths of mutual attraction between the respective atoms of the two elements.

The distance between atoms or ions is about one ten-millionth of a centimeter. But, in an impure crystal, there may be atoms of a foreign substance in between the normal lattice points, or at normal lattice points that are empty. Besides atoms of foreign substances, defects of the crystals themselves may exist in the form of local concentrations or absences of the atoms of the base material. It is thought that luminescence is due to any or all of these variations.

With the close crystal arrangement, electrons may move not only from one energy level to another, but from one atom or ion to another. Thus, in phosphors, the normal electron processes of absorption and emission of energy may become very complex and difficult to interpret. With the absorption of energy, electron shifts occur throughout the crystal, but



After its screen and internal coating are applied, the picture tube bulb and electron gun are merged by mount sealing machines, such as the one pictured here. Designed and built by Sylvania engineers, this machine fuses the gun mount to the bulb in 16 stages of heating, sealing, and cooling.

Courtesy Sylvania Electric Products, Inc.

it is believed that luminescence is due only to the electron shifts in the defect points.

The impurity material, usually added to these phosphors during manufacture, is called the ACTIVATOR and the points in the crystal lattice where its atoms or ions occur are known as fluorescent or active centers. When the crystal is excited, the displaced electrons of the activator atoms travel through the crystal for a considerable distance from their origin and eventually return to their own, or more probably to other active centers at which points their energy is transformed into luminescent emission.

As these active centers are distributed throughout the lattice structure or crystal atoms in a concentration of about one to a thousand, it is difficult for the liberated electrons to find their way back to the activator ion. Furthermore, electrons may be delayed or "trapped" near activator centers and in crystal faults. A certain amount of thermal agitation is required to reliberate the trapped electrons and permit them to wander to another trapping location or to a fluorescent center where they can cause light emission.

Because of this delay action, luminescence is produced for a short while after as well as during the time of crystal excitation. As stated, luminescence which occurs more than one ten-millionth of a second after excitation ceases is called phosphorescence. The phosphorescence of larger crystals lasts longer than that of smaller crystals because free electrons have an opportunity to wander farther in the more extended lattices.

Screen Phosphors

The phosphors used for picture tube screens are the sulfides and silicates. A very small quantity of activator or impurity material is added to the extremely purified base ingredients and then the mixture is crystallized.

For purposes of identification, cathode ray tube screen phosphors have been given the RETMA designations of P1, P2, P3, etc., up to about P25. Each phosphor has its own set of characteristics with regard to fluorescent color and period of phosphorescence. This period, called the "persistence", varies from a few microseconds to several seconds for the majority of the various phosphors. As examples, the P1 phosphor consists of zinc silicate with manganese as activator, has a fluorescent color of green, and a medium persistence of from .03 to .05 second. It is employed for the screens used in oscilloscope and radar cathode ray tubes. Also used for radar and for special oscilloscopes where the screen must hold tran-

#3

sient phenomena for comparison with previous effects, the P2 phosphor has a long persistence and a blue-green color.

At present, the P4 screen is used in television picture tubes in America. It is made of either zinc berylium silicate activated with manganese, zinc sulfide activated with silver, or a combination of both. The P4 screen has a white fluorescent color and a phosphorescence of about .005 second.

A variety of methods are available by which the phosphor material may be applied to the glass envelope. These are known as: (1) spraying, (2) dusting, (3) settling, (4) flowing on, and (5) electrostatic deposition. Each method offers advantages and disadvantages which depend upon the size of the envelope and screen, the type of screen, desired thickness of the screen, number of envelopes to be screened at a time, etc.

Image Contrast

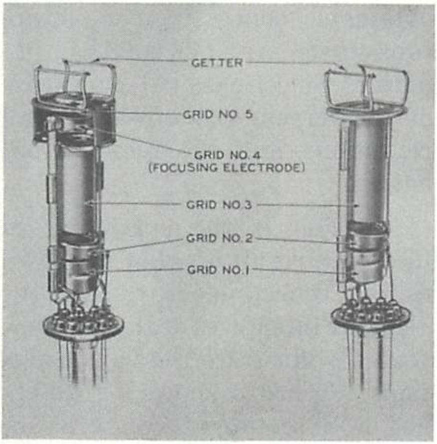
In the reproduction of a discernible image on the screen of a picture tube, contrast is one of the most important factors. Contrast has been defined as the difference in brightness between any two points or areas on the screen. The ratio of two brightness values is called the CONTRAST RATIO. Contrast may be divided into two categories: (1) the RANGE CONTRAST, which is a measure of the contrast range reproducing ability of the tube, and (2) the DETAIL CONTRAST, which is a measure of the contrast in the fine detail of the image. The detail contrast ratio determines the sharpness or clearness of the image and therefore is the more important.

Various factors which limit the obtainable contrast on a picture tube screen are: (1) halation, (2) normal reflections, (3) curvature of the screen, (4) envelope wall reflections, and (5) room illumination.

Halation is the spreading of light as a result of what is known as total reflection occurring at the glass air interfaces of the envelope wall. To illustrate the various actions, Figure 3 shows an amplified cross-section of a picture tube screen and envelope wall with the scanning beam striking the luminescent coating at point x, from where light rays emanate in all directions.

The ray x-a passes through the glass to air interface at right angles to the envelope wall surfaces and therefore suffers no refraction and very little reflection. Passing through the interfaces at angles of less than 90° to the glass surfaces, rays x-b and x-b′ are reflected about the same amount as ray x-a, but are bent, or refracted, as shown.

The refraction increases as the angle between the surface and these incident rays decreases, until finally, rays c and c′ are bent back into the glass. This condition is termed "total reflection." Rays c and c′ return to the inside surface of the envelope wall and again reach the interface between the glass and luminescent coating near points y and y′.



Structure of two types of electron guns. The one at the left is designed for electrostatic focus, while that at the right has its beam focused magnetically by means of a focus coil or magnet.

Courtesy Radio Corporation of America

The phosphor crystals do not touch the glass at every point of its surface, and the amount of glass surface in contact with the phosphor is called the percentage of optical contact. If the phosphor happens to be in contact with the glass at points y and y′, the light rays c and c′ will illuminate the phosphor. Reflected in the directions y-h and y′-h′, some of this light will emerge from the front of the tube screen, as shown.

Since y and y′ represent two points on the circumference of a circle centered at x, if a fairly high percentage of optical contact exists, an undesired circle of light will be produced around spot a. If the image at point h, for example is dark compared to that at point a, then the lighting of point y by the reflected ray c causes the element at h to be brighter than normal, and the contrast between it and element a is decreased.

If the phosphor is not in optical contact with points y and y′, then the interface is that of the glass wall and the vacuum inside of the envelope, and again the rays will be totally reflected. Under these conditions, light ray c will travel from y to point p instead of in the direction y-h. At point p total reflection again takes place, and so on along the envelope wall with light seen only at the points that the reflected ray touches the inter-surface of the glass with luminescent coating in optical contact. Since the unnatural lighting at y and y′ occurs only if optical contact exists at these points, a low percentage of optical contact minimizes halation.

Halation can limit the maximum contrast to a ratio as low as 6 to 1, and therefore it is the most important limiting factor. In a given tube, the amount of halation is determined by:

1. The index of refraction in the tube face.
2. The light transmission from the luminescent coating.
3. The percent of optical contact.
4. The light absorption of the tube face.
5. The thickness of the tube face.

The values of the first and second factors listed are fairly well fixed, and screen design is normally carried out in terms of optical contact, light absorption and tube face thickness.

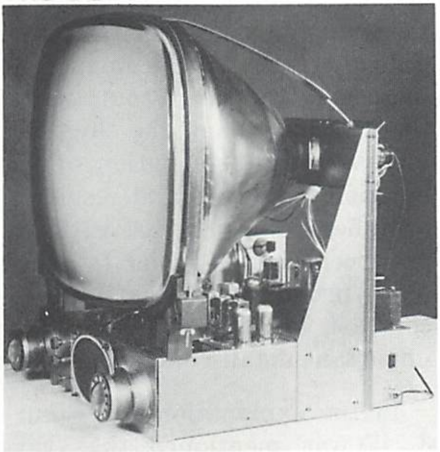
Conventional sprayed screens have an optical contact of about 30% and produce lower image contrast than settled screens which ordinarily have an optical contact of about 20%. The optical contact of dusted screens may be as low as 15% thus permitting an even greater degree of contrast.

Strange as it may seem at first thought, halation can be reduced by the use of a light absorbing material in the tube face. The light rays, which enable the observer to see the image, pass through the tube face once in a nearly perpendicular direction with relatively little attenuation, while those rays due to halation pass through the absorbing layer at least two extra times and, therefore, are attenuated to a greater extent. The light absorbing medium may take the form of a thin layer of an absorbing substance on the surface of the tube face, or the face may be made of a darkened glass. These are referred to as tinted face tubes.

Halation is affected by the thickness of the picture tube face in two ways: (1) decreasing the thickness causes the halation circles or bands to form closer to the scanning spot, thus affecting a smaller area of the image and increasing the range-contrast ratio, (2) increasing the thickness increases the attenuation of the halation light rays and results in a higher detail-contrast ratio. In practice, relatively thick faces are used, producing a loss in range contrast, but a gain in the more important detail contrast.

In the explanations of Figure 3, it was mentioned that rays x-a, x-b and x-b′ provide a small amount of reflection. When this reflected light illuminates the dark regions of the luminescent screen, the contrast between them and the bright area is decreased. Called NORMAL REFLECTIONS this effect results in an even distribution of undesired screen illumination, and therefore it is distinguishable from halation, which, as mentioned, takes the form of a more or less well-defined ring of light around the scanning spot.

As with halation, a low percentage of optical contact serves to minimize normal reflections, though compared to halation, these reflections are of rather small importance, limiting the contrast ratio to only about 60 to 1. About three times as detrimental to image contrast are the similar reflections caused by the safety glass usually employed in front of the picture tube.



Television receiver chassis view showing how the picture tube is well supported by a special mounting assembly.

Courtesy Stromberg-Carlson Co.

The effect of curvature of the screen and bulb envelope reflections is shown in Figure 4. Here, point x represents a bright portion of the image and point y a dark portion. The light from point x scatters in all directions, some coming through the tube face in the direction x-a, and some going directly to point y as indicated by line 1, a path made possible by screen curvature. Also, light from point x travels to the envelope wall, to points m and n, for example, and is reflected to point y.

The light which reaches y by these various paths travels through the tube face in the direction y-b, so that the portion of the picture at y is not as dark as it should be. The brighter the light portions of the picture the greater this illumination of the dark areas, and thus the greater the reduction of contrast. The contrast ratio is limited to approximately 70 to 1 by the effects of curvature of the screen, and to about 200 to 1 by envelope wall reflections.

Room illumination tends to light up the entire screen thereby making all the portions of the image brighter than they should be. Since the brightness difference produced in the bright parts of the picture is small compared to that of the dark portions, the contrast between them is decreased. The ratio varies considerably with conditions in any particular case. However, the effects of room illumination are reduced by the use of the tinted face tubes. The tinted face reduces the amount of room light that can reach the screen and thus improves contrast.

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A notable development in picture tube screen design is the application of a light reflecting metal layer on the inner or beam side of the luminescent screen. Consisting of a thin coating of aluminum, this layer permits the beam electrons to pass and strike the luminescent coating, but reflects the light forward. This action approximately doubles the tube light output and eliminates the effects of envelope wall reflections and curvature of the screen, resulting in an improvement of range contrast by a factor of three to ten times. However, as the arrangement does not prevent halation, the more important detail contrast is only slightly improved. When it includes this coating, a picture tube screen is referred to as being "aluminized".

#5

ELECTRON GUN

Electrodes

The **electron gun** is a group of closely related electrodes which produce an electron beam of the desired small diameter. In this assembly, the essential components are the cathode which supplies the electrons, and an anode which pulls them away from the cathode and accelerates them toward the screen. Between the cathode and anode are located one or more grids to properly control the diameter and intensity of the beam.

The structure of one type of electron gun is shown in the cross-sectional drawing of Figure 5. Starting at the left, the indirectly heated cathode is a tubular sleeve which is surrounded by a larger diameter tube, grid No. 1. The third tube-shaped electrode serves as the second grid, and the fourth is the anode. In order to help confine the electrons to a beam, the grids and anode each contain a disk, at the center of which is a small hole through which the electrons pass. These holes or apertures provide the only path by which electrons can reach the screen.

Ion trap magnet. In this view, the magnet is at the bottom, and the two curved arms are connected with a spring which supplies the proper tension to hold the assembly in place around the neck of a picture tube.

Courtesy Quam-Nichols Co.

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In operation, the anode is from 12,000 to 22,000 volts positive with respect to the cathode. Due to this difference of potential, the strong electric field between these two electrodes accelerates the electrons to a high velocity.

Grid No. 1 is the control grid, and it is operated negative with respect to the cathode and so controls the number of electrons in the beam, much like the control grid of an electron tube. Grid No. 2 is operated at 400 to 500 volts positive, and prevents interaction between the electric fields of the control grid and anode.

In the gun, there is an electric field of force between each pair of adjacent electrodes. These electric fields not only control the speed of the electrons, but they also confine the beam to a small diameter. Thus, the beam passes through the holes in the disks with almost no electrons actually striking the disks.

Ion Trap

Unless preventive arrangements are made, a permanent dark area known as an ion spot is formed in the center of the picture tube screen. Negative ions are emitted from the cathode, along with the electrons. Attracted by the positive anode, the ions form a beam, and travel to the screen also. Since the ions are very heavy compared with the electrons, they strike the screen with sufficient force to damage it, thus producing the spot.

To prevent the formation of an ion spot, **ion trap** type electron guns have been devised. The gun of Figure 5 is one such type. Called a "tilted gun", this unit has its axis at an angle to the axis of the tube. Grid No. 2 and the anode are formed so that the gap between them is diagonal rather than at right angles to the gun axis. When the electrons and ions encounter the area between these electrodes, they are deflected from their original direction by the electric field in this gap.

#9

As shown, the ion trap magnet is mounted on the outside of the tube neck. Its magnetic field penetrates the neck and gun, and deflects the electrons so their path is parallel with the axis of the tube, indicated by the solid line in the Figure. However, the magnetic field has little effect on the heavier ions. They continue on their deflected path, as shown by the dashed line, until finally trapped by the anode.

A second type of ion trap gun is shown in Figure 6. Called the "bent-gun", this unit consists of an indirectly heated cathode, two grids, and an anode, and operates like the gun of Figure 5 so far as formation of the electron beam is concerned. As shown, all of the gun except the forward part of the anode is at an angle with the tube axis.

#7

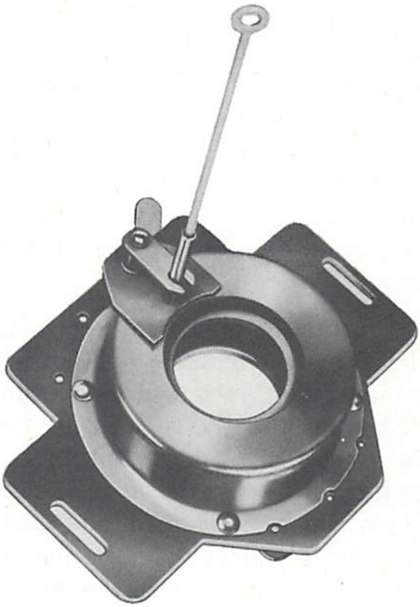
The ion trapping action is based on the same principle as that of the gun of Figure 5. Electrons can be deflected easily by either an electric or magnetic field, while the relatively heavy ions are affected considerably less by a magnetic field than by an electric field. Therefore, in the bent-gun of Figure 6, the field of the ion trap magnet bends the electron beam to bring it parallel with the axis of the tube, but the ions continue in almost their original direction to be trapped by the anode.

In service and maintenance procedures, the technician adjusts the position of the ion trap magnet for best operation.

An additional advantage of an aluminized screen is that the aluminum coating offers some protection to the phosphor against the bombardment of any ions remaining in the beam.

FOCUS METHODS

Although electric fields in the electron gun provide a beam of small diameter, it is necessary to decrease the beam diameter further by means of a **focus** system. The action is referred to as focusing because the effect on the electron beam is like that produced by an optical lens on light rays. In the picture tube, either a magnetic field or an electric field is employed to focus the electron beam. When employed in this manner, these fields are called electron lenses. These electron lenses or focusing fields are in addition to those mentioned previously in the description of the electron gun. Depending upon the type of field employed, the focusing methods are called magnetic focus, or electrostatic (electric) focus.



Easily accessible adjusting rod enables this permanent magnet type focusing magnet to be moved to the point which provides best focus.

Courtesy Heppner Mfg. Co.

Magnetic Focus

Magnetic focusing of an electron beam is illustrated in the simplified diagram of Figure 7. As indicated by the solid line, electrons traveling along the axis of the tube are not affected by the flux lines of the focus coil, but any divergent electrons, as shown by the dashed line, cut across the magnetic flux lines. The reaction between the magnetic fields of the electrons and focus coil field causes the divergent electrons to turn back toward the axis and arrive at the focal point on the screen.

This action is shown in greater detail by the drawing of Figure 8 which represents a cross section of the neck of the tube inside the focus coil. The large dot in the center represents the beam of electrons which is assumed to be moving straight up out of the paper, while the small dots represent the flux lines of the focus coil.

Electrons moving along a path parallel to the axis of the tube are not affected by the magnetic field because they do not cut the flux lines. Without the focus coil any divergent electrons would finally strike the side of the tube as indicated by path No. (1). However, the flux lines of the focus coil combine with the magnetic field about the moving electron so that the total or resultant field is strengthened on one side of the electron and weakened on the other.

In accordance with the left-hand rule for electron flow, the direction of the magnetic field about the divergent electrons is indicated by the small curved arrow drawn around the line which represents path No. (1). With the focus coil flux lines assumed to be in a direction up out of the page, the resultant magnetic field will be weaker above the divergent electrons and stronger below. Thus, like a conductor, the electrons will be pushed toward the weaker field region, as indicated by the small arrow "F," and tend to follow path No. (2).

If the flux lines of the focus coil are increased, the electron path curvature is increased also. As shown by path No. (3), the electrons curve around and return to the axis of the tube. A further increase of the flux lines causes the electrons to travel in a smaller circle as shown by path No. (4).

At the same time that the circular motion takes place, all the electrons move from the gun toward the screen of the tube. Therefore, divergent electrons follow paths which actually are spiral in shape. By selecting the proper direct current in the focusing coil, the number of flux lines is adjusted so that the divergent electrons return to the tube axis at the same instant they reach the screen. When focused properly, both the divergent and axis electrons strike the screen at the focal point, to form a spot of small diameter.

The electromagnetic focus coil can be replaced with a permanent magnet. In this case, focus adjustment is accomplished by varying an air gap in the magnetic circuit.

Electrostatic Focus

An additional electrode is employed in the electron gun to provide the focusing field in tubes using electrostatic focus. The basic arrangement of the electrodes is shown in Figure 9. Here, the anode of Figures 5 and 6 is divided into two sections. As indicated in Figure 9, the two sections taken together may be called the anode, or, if considered separately, may be designated as grids Nos. 3 and 5. These sections are connected together within the tube, and thus operated at the same high voltage of 12 kv or more. The added electrode is grid No. 4, called the focusing electrode.

In most electrostatically focused tubes, this electrode is operated at some positive voltage between 0 and 400 volts. The focus voltage is taken from the slider terminal of a potentiometer to permit focus adjustments. Tubes employing focus voltages in this range are called "low voltage electrostatic" tubes to distinguish them from a number of types which employ focus voltages of several kilovolts.

In the gun of Figure 9, curved lines indicate the electric lines of force between the anode and the relatively negative focusing electrode. Electrons traveling along the axis of the tube are not affected by this electric field since it is symmetric about them.

Deflection yokes, such as the one pictured, provide continuously varying magnetic fields to cause the electron beam to sweep over the screen. The wires of one pair of coils can be seen here.

Courtesy Chicago Standard Transformer Corp.

However, as the dashed line shows, divergent electrons encounter the electric lines of force. As there is a difference of potential along the lines of force, the electrons tend to move in the direction of the lines, but their forward motion carries them across the lines. The net result is a slight change in direction as each line is crossed, with the electron returning toward the axis as it leaves the gun. The focus voltage adjustment provides an electric field of the proper strength such that divergent electrons return to the axis just as they arrive at the screen.

In one type of electrostatic focus gun, the focus electrode is connected internally to the cathode. With this arrangement, a source of focusing voltage is not needed. These tubes are known as self-focus or automatic focus tubes. They require extremely close tolerances in gun structure, which fact increases the cost of their production. Also, their proper focusing action requires that none of the other electrode voltages vary by more than 5%. Due to these disadvantages of the automatic focus tubes, the adjustable focus voltage types are in more common use.

DEFLECTION

To form the pattern of horizontal lines or raster on the screen of the picture tube, varying magnetic fields are employed. Actually, two fields combine in the neck of the tube to form a resultant field through which the beam electrons pass on the way to the screen. Separate vertical and horizontal fields are produced by two pairs of **deflection coils**, assembled into a unit called the **yoke.** The yoke is mounted around the neck of the tube, at the point where the neck joins the bulb, as shown in Figure 1.

The drawing of Figure 10 shows how the pairs of coils, called vertical and horizontal respectively, are positioned. One pair of coils serves to deflect the beam in a horizontal direction while the other pair moves the beam vertically.

The small circle in the center of the drawing represents any one or all of the electrons which travel from the electron gun toward the screen, or out of the drawing. Thus, according to the left hand rule, the magnetic lines of force around the electron are in a clockwise direction as indicated by the two small circular arrows.

Each pair of deflection coils is connected in series across a separate source of alternating current. At the instant the current in the vertical coils is in a direction to cause flux lines from left to right, as shown, the electron and coil flux lines are in the same direction above and in opposite directions below the electron. Thus, the resultant flux above the electron is strong while that below is weak, and the electron is deflected downward as indicated.

During the following alternation of the a-c cycle, the flux lines of the vertical coils reverse direction, while those of the electron do not change. Therefore, the flux above the electron is weakened while that below is strengthened, and the electron is deflected upward.

A similar action, produced by the resultant flux of the horizontal deflection coils and the electron, causes deflection in the horizontal direction. Therefore, two pairs of deflection coils, arranged as in Figure 10 with alternating currents of proper frequencies in them, deflect the electron beam so that it scans the entire screen surface.

In both pairs of deflection coils, the alternating currents have sawtooth wave-form. As a result, the horizontal deflection coils cause the beam to move at a constant speed from left to right on the screen, and then snap back quickly to the left side, for each a-c cycle. The movement from left to right produces the useful horizontal line, called the "trace".

During the "retrace", from right to left, no line is produced, because a blanking pulse is applied to the gun to cut off the beam. The sawtooth current in the vertical coils causes the beam to travel from the top to the bottom of the screen at a constant speed, while approximately 240 horizontal lines are traced, and then snap quickly back to the top.

Some years ago, a few types of television picture tubes employed the electrostatic deflection system now used in oscilloscopes. Sawtooth voltages were applied to two pairs of deflecting plates located in the neck of the tube. The beam was deflected due to the electric attraction and repulsion of the plates.

All present day television receivers employ magnetically deflected picture tubes. For this reason, we have given the details of this deflection method only.

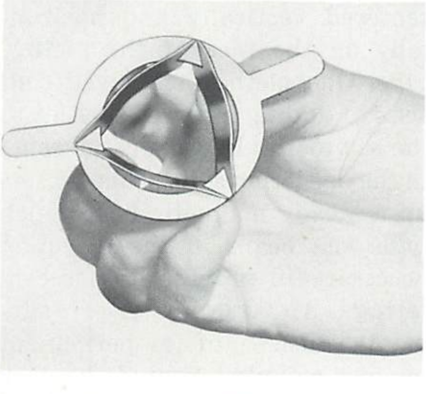
CENTERING

The produced raster must be centered vertically and horizontally on the face of the picture tube. One method employed consists of adding a direct current to the sawtooth alternating currents in the deflection coils. This d-c sets up a steady magnetic field which pulls the beam in the direction necessary to provide proper centering. An alternative arrangement consists of a permanent magnet mounted around the neck of the tube. Rotation of this magnet permits changing the direction of its field to center the raster.

PICTURE TUBE STRUCTURE

Figure 11 shows the arrangement of the focusing coil and deflection yoke on the neck of a picture tube. Here, the electron gun is the tilted type explained for Figure 5. The inside surfaces of the glass bulb and most of the neck are coated with a layer of conductive material. This coating makes electrical contact with the anode (Grid No. 3) by means of the curved spring supports at the forward end of the gun.

The anode voltage is supplied through the bulb cap to the coating, which serves as an extension of the anode. Thus, operated at the high anode voltage, the internal conductive coating provides a uniform field through which the electrons travel to the screen. Called the collector, this coating contacts the screen, and thus provides a path by which the beam electrons leave the screen and return to the power supply.



One type of centering magnet which is placed around the picture tube neck and rotated as necessary to properly center the picture.
Courtesy Heppner Mfg. Co.

A second tube arrangement is shown in Figure 12. In this case, the electron gun includes a focus electrode, grid No. 4. Therefore, there is no focus coil. However, this tube assembly employs a centering magnet which is located between the gun and the deflection yoke. Like the tube of Figure 11, there is an internal conductive coating, or collector, connected to the anode (grids 3 and 5).

In addition, the tube of Figure 12 has an external conductive coating. Separated by the glass wall of the bulb, the two coatings form a capacitor with a capacitance of 500 to 1500 $\mu\mu$f in the various tubes. With the external coating connected to ground, and the internal coating to the high voltage supply, this capacitance serves as the output filter for the voltage supply. Another function of the external coating is to shield the tube from stray magnetic fields.

Although represented simply in Figures 11 and 12, the ion trap magnet has curved pole pieces which extend down around the neck of the tube. The magnets shown are called "single", and are the most common. Some tube types have a gun structure which requires a "double" ion trap magnet. Another variation is that in which the magnet is inside the neck, called the "internal" ion trap magnet.

SCHEMATIC SYMBOLS

As in other types of electron tubes, the gun electrodes have leads which extend through the picture tube base to pins to provide connection to the external circuits. The basing diagrams of the commonly used picture tubes are given in Figure 13. In these diagrams, the various grids and anodes are all indicated as grids, and placed above the cathode in the order the beam passes through them. Thus, the control grid is designated G_1, the accelerating electrode designated as grid G_2, and so on.

In all the types using the bases illustrated, the anode connects through the internal conductive coating to a "cap" located in a small cavity or indentation in the glass bulb. In other types of tubes, the glass bulb is replaced by a metal shell. A glass face plate fits into the front end of the shell, and a glass neck is attached to the other end. For these tubes, the lead from the high voltage supply connects to the lip of the metal shell. With this arrangement, the shell is at high voltage, and serves as the collector. With both glass and metal type tubes, the connection to the anode is indicated by the small rectangle labeled "A" on the base diagrams.

On all four of the bases shown, the pins are spaced such that the base could contain 12 pins. Each pin is numbered as it would be if all 12 pins were present. Thus, the two 5-pin bases, 12-D and 12-N, have pins numbered, 1, 2, 10, 11, and 12. The 6-pin bases, 12-L and 12-M, have pins 1, 2, 6, 10, 11, and 12. In all four, the heater connects to pins 1 and 12, the cathode to pin 11, the control grid to pin 2, and the accelerating grid to pin 10. In the tubes using the 12-D and 12-N bases, the third "grid" in the diagrams is the anode, and connects to the bulb cap, as indicated. In the 12-L and 12-M based tubes, the anode consists of grids 3 and 5, which are connected together internally. The fourth grid is the focusing electrode, and connects to base pin 6.

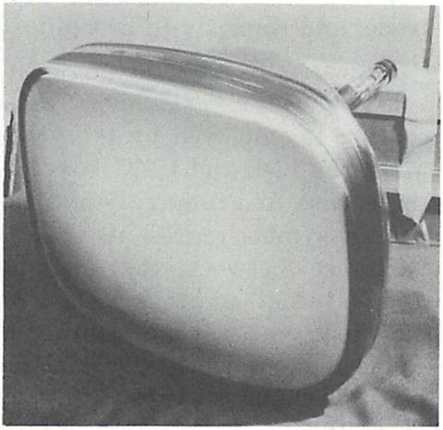
#10

Indicated by the rectangle labeled "C", an external conductive coating is employed by the tubes using the 12-L and 12-N bases. In these base diagrams, a small capacitor symbol represents the capacitance between the internal and external coatings. Also, as explained, the internal coating is connected to the anode. One manufacturer employs the term "ultor" to designate the combination of electrodes which comprise the anode, or are internally connected to the anode. For example, in a tube with the 12-D base, the ultor is composed of the third grid and the collector. In the case of a 12-L based tube, grids 3 and 5 and the collector make up the ultor.

TYPICAL PICTURE TUBES

A considerable number of picture tube types have been developed. They differ from one another with regard to size, shape, envelope, screen, electron gun, focusing method, and so on. Some tubes employ a round face plate. The diameter of these round face plates formed the original basis for designating the tubes as 16-inch, 19-inch, etc.

Many tubes now in use have rectangular face plates. This shape is the same as that of the raster produced by the scanning beam. To produce a picture of the same size, a round-face tube requires a diameter equal to the diagonal across the face of the rectangular tube. Therefore, to permit comparison on the basis of equal picture size, the rectangular picture tubes are designated as 17-inch, or 21-inch tubes, according to the dimensions of the diagonals.



A typical rectangular picture tube, the 21ZP4 measures 21-7/32 inches along the diagonal across its face. This dimension provides a picture area of approximately 250 square inches. A large percentage of television receivers employ picture tubes of this size and general type.

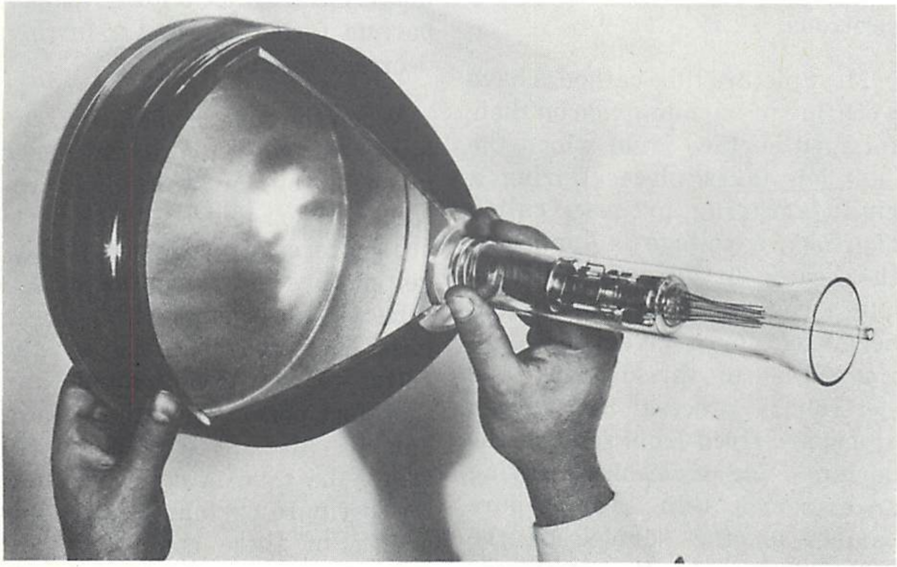
Courtesy Allen B. DuMont Laboratories, Inc.

As an example, a commonly used "17-inch" picture tube is the rectangular-faced 17HP4. The face of this tube is only 12¼ inches high and 15⅜ inches wide. However, its diagonal is nearly 17 inches, and it provides a picture approximately the same size as that obtained with a 17-inch round-face tube. The 17HP4 employs electrostatic focusing, a singel ion trap magnet, and has an external conductive coating. Its face plate is tinted to improve contrast ratio. The 12-L base diagram of Figure 13 applies to this tube. A later model of this tube, designated 17HP4A, has a face plate which is both frosted and tinted. The frosted face diffuses reflections of bright objects, such as lamps, which interfere with viewing.

A typical picture tube in the 21-inch size is the 21ZP4. This tube has a glass envelope with a rectangular, tinted face. It uses magnetic focusing, and a single ion trap magnet, with base connections shown by the 12-D diagram. A variation of this tube, the 21ZP4A, has an external conductive coating as indicated by the 12-N base diagram. A second feature consists of employing an aluminized screen in this tube, and is designated 21ZP4B.

A commonly used metal body tube is the 21MP4. This unit is a rectangular picture tube with a metal shell, and a tinted and frosted glass face plate. Indicated by the 12-M base, the electron gun contains a focusing electrode for electrostatic focusing. A single ion trap magnet is used.

The 24CP4 is representative of the 24-inch tubes. It is a rectangular glass tube with tinted face plate, has an external conductive coating, uses magnetic focus and a single ion trap magnet. The 24CP4A version has a face plate which is both tinted and frosted. The 12-N base diagram applies to both tubes. A fifth typical type is the 27EP4, a rectangular glass picture tube with a tinted and aluminized face. It employs magnetic focusing and a single ion trap magnet. The 12-D base diagram shows the electrode connections in this tube.



Cut-away view of a round face picture tube showing construction and arrangement of the electron gun.

Courtesy North American Philips Co., Inc.

PICTURE TUBE FAULTS

Picture tubes can develop various defects which impair the picture quality or result in complete loss of the picture. Of course, some of the symptoms produced by these defects can be produced by faults in other parts of the receiver also. Usually, the service technician checks these other possible sources before concluding that the picture tube is definitely at fault.

The most common type of picture tube failure is that in which the entire picture is dim, even with the brightness control turned all the way up. This insufficient light on the screen is due to the fact that the cathode is not emitting enough electrons. How this condition comes about can best be understood by considering the action by which the cathode emits electrons.

Most picture tube cathodes have a coating of barium-oxide on their forward surface from which the emission takes place. During a manufacturing process, called "ageing", a voltage is applied to the heater to heat the cathode, and a controlled cathode current permitted for a given period of time. Due to this heating and electrolysis process, the oxygen atoms are freed from some of the barium-oxide molecules, leaving an extremely thin layer of pure barium on the surface of the barium-oxide. In the completed tube, the electron emission is much greater from the very thin pure barium layer than from either barium-oxide or a thick solid coating of barium.

At all times, whether the tube is operating or not, gases are given off by the other electrodes of the gun and by the walls of the picture tube. These gases unite with the pure barium layer on the cathode, effectively "poisoning" it. When the tube is operating, the heater supplies the heat and the beam current the electrolysis needed to free more oxygen atoms from the barium-oxide, and thus perpetuate the emitting layer. However, if the poisoning action operates faster than the barium formation, the emission is reduced. With less emission, there is less electrolysis, a lower rate of barium formation, and a further decrease in emission.

When the tube is operating, the beam electrons ionize the gases given off by the walls and electrodes. When ionized, these gases are more easily collected by the getter. However, when the picture tube is not being used, these gases are not absorbed by the getter to any great extent, and therefore poison the cathode more quickly. Also, as it is not operating, the tube is not reforming the lost pure barium. As a consequence of these conditions, the cathode often becomes a poor emitter more rapidly than in a picture tube which is being used.

It is possible to rejuvenate or reactivate low-emission picture tubes by means of various instruments commercially available. One method consists of duplicating the manufacturer's ageing process as described above. Another consists of "boiling" off a quantity of the cathode coating. These repair methods assume considerable importance when it is realized that 80 to 90 per cent of defective picture tubes are faulty due to loss of emission.

The remaining 10 to 20 per cent of picture tube failures result from a variety of defects. Among the most frequent are gassy tubes, shorts between elements, open connections to elements, loose elements which cause intermittent opens or shorts. When gassy, a picture tube exhibits excess brilliancy which cannot be reduced greatly by turning down the brightness control. Insufficient brightness can be caused by an improperly adjusted ion trap, or the wrong type of ion trap.

Other defects include air leak, loose or cracked base, ion burn, holes and cracks in screen phosphor, magnetized metal cone, bubbles in glass face, internal arcing due to poor internal anode coating, and many others. The various means of determining the type and location of the different faults, and the repairs or adjustments that can be made are explained in the lessons on television servicing.

The picture tube is the last stage in the video channel of the television receiver, and the sound channel terminates in a loudspeaker. At some point, the sound and picture signals are separated, the video applied to the picture tube and the sound i-f to the sound channel. Beginning at this separation point, the next lesson follows the sound signal through the various stages of the complete sound channel.

* * *

IMPORTANT DEFINITIONS

DEFLECTION—Movement away from a position. In the television picture tube, the scanning motion of the electron beam.

DEFLECTION COILS—A pair of coils which produce a varying magnetic field to deflect the electron beam horizontally or vertically in a picture tube.

ELECTRON GUN—The group of electrodes located in the neck of the picture tube which produce a fine beam of electrons and direct it toward the screen.

FOCUS—The action by which an electric or magnetic field causes the beam electrons to converge to form a beam of small diameter at the screen of the picture tube.

ION TRAP—In a picture tube, the electron gun arrangement, in conjunction with a magnet, which traps the negative ions and prevents them from reaching the screen.

YOKE—The assembly consisting of the vertical deflection coils and the horizontal deflection coils. It surrounds the neck of the picture tube.

STUDENT NOTES

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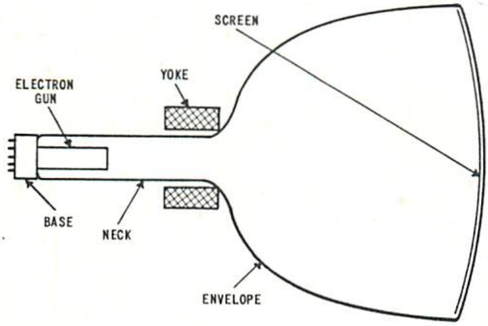


FIGURE 1

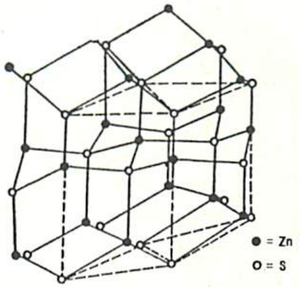


FIGURE 2

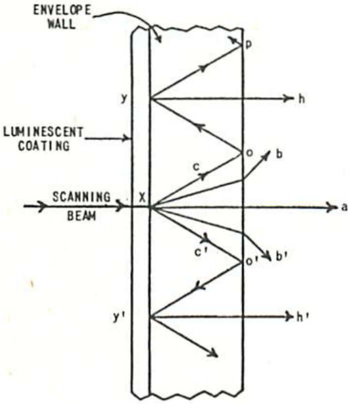
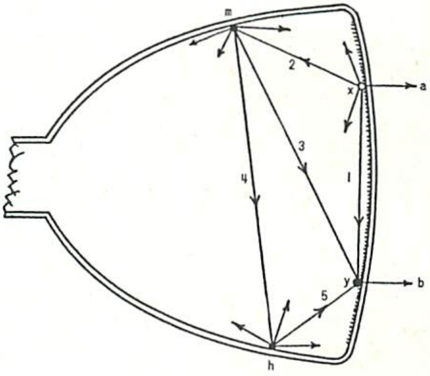


FIGURE 3



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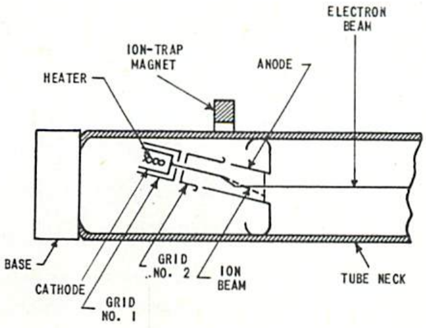

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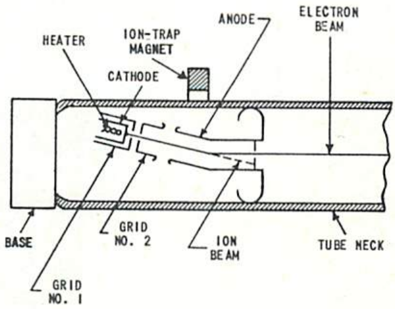


FIGURE 6

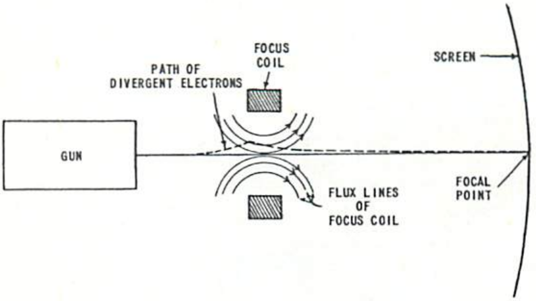
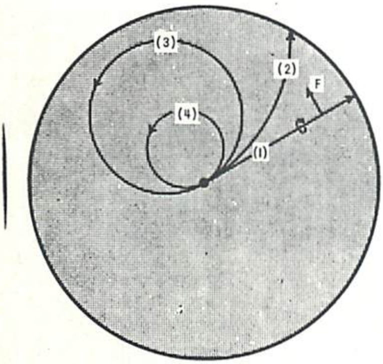


FIGURE 7



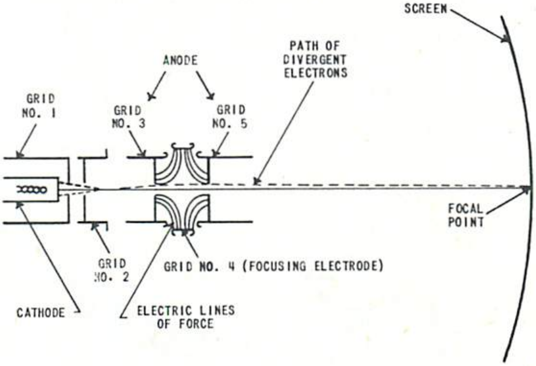


FIGURE 8

FIGURE 9

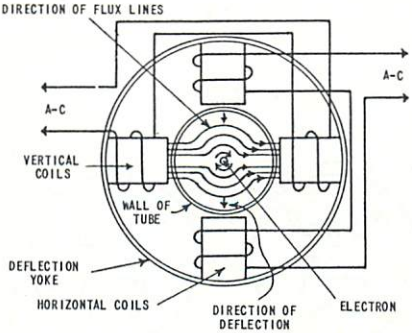
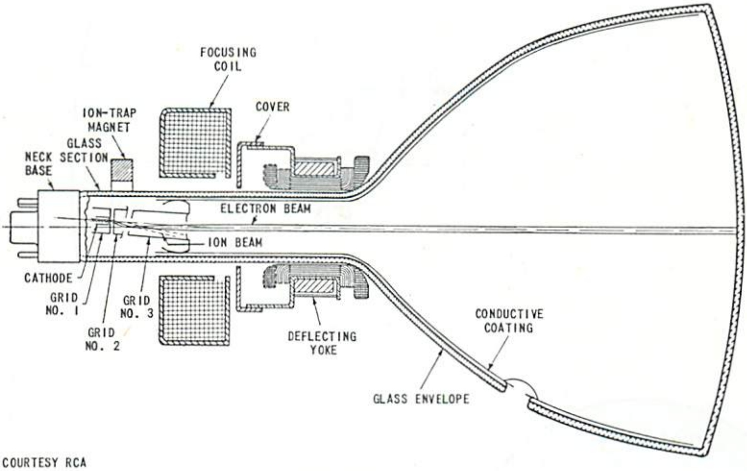
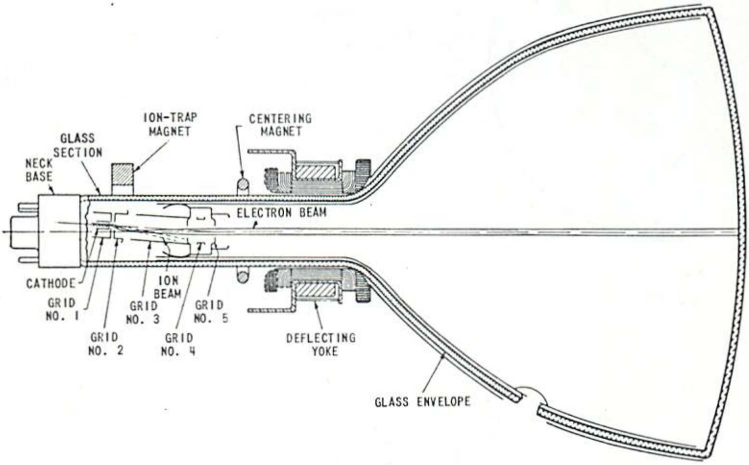


FIGURE 10



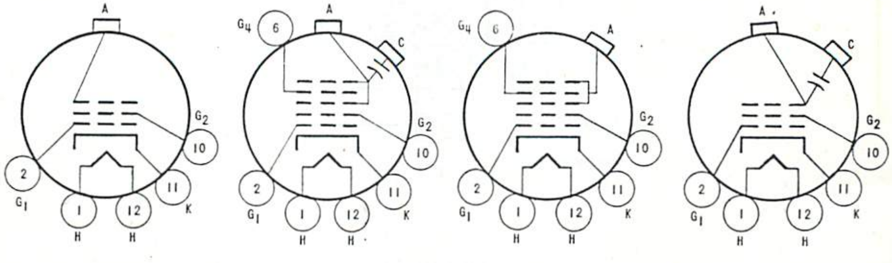
COURTESY RCA

FIGURE 11



COURTESY RCA

FIGURE 12



12-D 12-L 12-M 12-N

FIGURE 13

FROM OUR *Director's* NOTEBOOK

THE WINNER

The man who wins is the man who does,
The man who makes things hum and buzz,
The man who works and the man who acts,
Who builds on a basis of solid facts;
Who doesn't sit down to mope and dream,
Who hasn't the time to fuss and fret,
But gets there every time—you bet.

The man who wins is the man who wears
A smile to cover his burden of cares;
Who knows that the sun will shine again,
That the clouds will pass, and we need the rain.
Who buckles down to a pile of work
And never gives up and never will shirk
Til the task is done, and the toil is sweet,
While the temples throb with red blood's heat.

The man who wins is the man who climbs
The ladder of life to the cherry chimes
Of the bells of labor, the bells of toil,
And isn't afraid his skin will spoil
If he faces that shine of the glaring sun
And works in the light 'til his task is done;
A human engine with triple beam
And a hundred and fifty pounds of steam.

Yours for success,

W. C. DeVry

DIRECTOR

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